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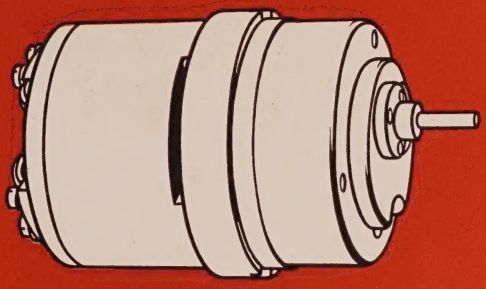
TECHNIQUE

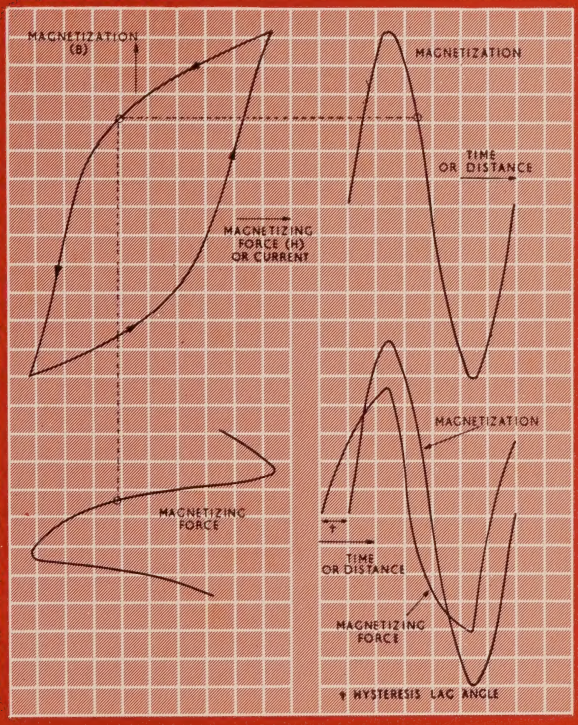
MUIRHEAD

A JOURNAL OF INSTRUMENT ENGINEERING

VOLUME NINE · NUMBER TWO

APRIL 1955





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THE FRONT COVER

High frequency hysteresis motors offer many advantages in precision instruments where a constant speed is required, but, on account of their high speed, present problems of lubrication and bearing design which have hitherto made their reliability suspect. The D-565 Motor illustrated on the front cover overcomes these difficulties by incorporating an integral gear-box, so that even though the rotor speed is 10,000 rev/min when fed with power at 1,000 c/s, the output spindle speed is only 720 rev/min. The reliability of these motors has been proved in Muirhead Facsimile Transmitters and Receivers.

The curves show how the hysteresis loop of a magnetic material causes the magnetization effectively to lag behind the magnetizing force (or current) producing it. Applied to a hysteresis motor this means that the rotor magnetic axis lags behind the rotor field axis by a constant angle and the motor torque results from the force tending to align them. This torque is substantially constant as the rotor accelerates; when synchronism is reached the rotor magnetic axis becomes fixed and the motor will behave like an orthodox synchronous machine, the lag angle depending on the load.

A full description of the operation of the hysteresis motor is given in 'Technique', Vol. 5 No. 4.

PHYSICAL SOCIETY EXHIBITION

The Physical Society Exhibition will be held at the Royal Horticultural Society's New Hall, Greycoat and Elverton Streets, Westminster, S.W.1 (just behind Victoria Street from Artillery Row). We shall be exhibiting the instruments mentioned in the last issue of *Technique* on Stand 86.

The exhibition is open on the following days:

Monday 25th April	2 p.m. - 8 p.m.	Wednesday 27th April	10 a.m. - 8 p.m.
Tuesday 26th April	10 a.m. - 8 p.m.	Thursday 28th April	10 a.m. - 5 p.m.

1955 CATALOGUE

Our new catalogue is now available, and we invite all who are interested to write for a copy. When applying, please state the name of your firm and the position you occupy as well as your name and address.

MUIRHEAD & CO., LIMITED

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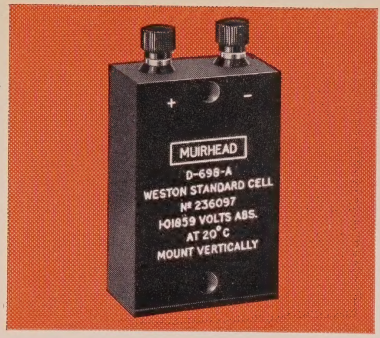


A NEW WESTON STANDARD CELL

THE D-698 Miniature Standard Cell is the latest addition to our range of Weston cells. It combines the robustness and small size of our D-550 Miniature Standard Cell with a high capacity previously only available in larger types such as our D-402 Cell. In this new cell we have reverted to the classical H-construction (the D-550 Miniature Cell employs a single glass tube with a glass web dividing the electrodes) but in a modified form to minimize the temperature difference between the legs of the H and resultant changes in e.m.f. A comparison of the D-698 and the D-550 cells shows that although the volume of the former is almost twice that of the latter its more practical proportions will enable it to be employed in positions where the use of the D-550 cell is precluded. Connexions are brought out to two terminals on the top of the black Bakelite case and provision is made for base or side mounting. The cell is intended to be used vertically, but a misalignment of several degrees will not affect its performance.

ELECTRICAL CHARACTERISTICS

The e.m.f. is 1·01859 volts absolute, guaranteed to within +110 μV and − 90 μV at 20°C for individual cells. The temperature coefficient of e.m.f. is approximately − 40 μV/°C between 15°C and 25°C, but varies with the temperature. The table below shows the way in which the e.m.f. varies between 10°C and 40°C.

Temp. °C	10	15	20	25	30	35	40
e.m.f.Vabs.	1·01889	1·01877	1·01859	1·01836	1·01810	1·01780	1·01748

The internal resistance is approximately 600 ohms at 20°C, increasing as the temperature falls.

CAPACITY AND DISCHARGE RATE

Because the capacity of this new cell has been increased it might be thought that the current rating would be increased proportionally. This, however, is not the case; the discharge rate depends on many other factors, such as the length of time for which the current flows and the 'rest' period before the cell is used again.

The standard cell is a standard of e.m.f., and ideally no current whatever should be taken from it. In practice this is not possible; in potentiometric work a small current is taken during the balancing process. While this current flows the terminal voltage of the cell is reduced, and in a recent paper in the *Journal of Scientific Instruments** the components of the voltage drop have been analysed, with results which have thrown light on the need for allowing a period of recovery after current has been taken.

Measurements were made on thirteen cells of different manufacturers under various conditions. The results showed that apart from the IR drop in the cells an additional voltage drop occurred because of chemical changes at the electrodes associated with the generation of the current. This voltage drop was small but increased with the current and *also with the time for which it flowed.* When the current was stopped the terminal voltage rose but did not return to its initial value until some time had elapsed — the time required depending on the magnitude and duration of the preceding current-flow. For example, with a current drain of 10 μA the IR drop was 8 mV, but the additional voltage drop was 10 μV after one minute and 120 μV after five minutes. When the current ceased the voltage rose to within 100 μV of its initial value immediately, but took 10 minutes to return to within 10 μV of the original value, and 20 minutes to come within 1 μV. On increasing the current to 100 μA *for only one second* the open-circuit voltage of the cell fell by 30 μV and took two minutes to return to within 10 μV of its initial value.

These tests showed that all cells recovered their initial e.m.f. completely when allowed sufficient time, and the conclusion reached by the authors of the paper was that a current of 10 μA may safely be taken for a minute or so provided that a recovery period of the same duration is allowed. The working life of the cell will obviously depend on the magnitude and duration of the current drain.

These findings confirm tests which we ourselves have made on the D-698 Cell; on the basis of these tests we state that a current of 20 μA may be taken from this cell for short periods. We recommend, however, that every standard cell should be regarded as a reference voltage standard, and not used as a source of current (no matter how small).

*HARTSHORN, L. & MANNING F. A. The behaviour of standard cells under conditions which include the generation of appreciable current. *Journal of Scientific Instruments*, **31** (1954), pp. 115-118.

A.C. SERVOMOTORS AND SERVO AMPLIFIERS

By A. E. W. Hibbitt B.Sc.*

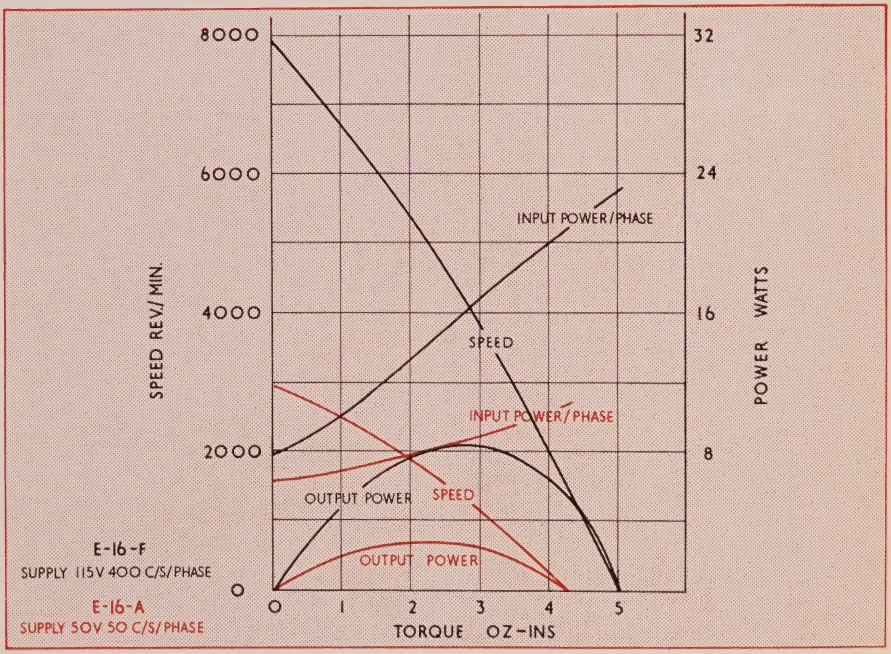
IN industrial and service spheres instrument-type servo mechanisms are being employed on an increasing scale for purposes of automatic and remote control, remote indication, and analogue computation. The motive power for these servo mechanisms may be hydraulic or pneumatic, but more usually is provided by an electric motor energized from an amplifier, which may be of either the electronic or magnetic type. In a large number of systems, notably those employing Magslips for remote position control, the error signal is in the form of amplitude modulation of an A.C. carrier. For such servos it is often convenient to employ an A.C. amplifier and an A.C. motor to provide the motive power for the system, and for this reason the range of small A.C. servomotors and amplifiers described below has been produced.

The servomotors are built in the three standard Magslip frame sizes — 1½-inch, 2-inch and 3-inch. Servo amplifiers are available for several models and other types are being developed.

SERVOMOTORS

Magslip A.C. servomotors are all two-phase induction motors. The 2-inch and 3-inch sizes employ a wound rotor, and the 1½-inch size a squirrel-cage rotor. The torque-speed characteristic of all types approximates to a straight line, maximum torque being obtained in the stalled condition. This form of characteristic is desirable since the reduction of torque with increase in speed corresponds to viscous friction in the servo system and hence improves the damping. The motors will not run as single-phase machines when one phase only is energized; this is essential since a servomotor must stop when the supply is removed from the control winding.

Two versions of the 2-inch motor are available. One, the E-16-A two-pole motor, is based on a Service motor and is suitable for



*Muirhead & Co., Limited.

use on a 50 c/s supply. The other, the E-16-F six-pole motor, is intended for use on a 400 c/s supply. The torque-speed and power consumption characteristics of these two motors are shown on page 12. The 1½-inch and 3-inch servomotors at present available are suitable for use on 50 or 60 c/s supplies.

A characteristic feature of the 2-inch and 3-inch Magslip servomotors is the resistor carried on a circular insulating former mounted on the spindle. In order to achieve the desired linear torque/speed characteristic it is necessary to terminate the rotor winding with a suitable resistance. The heat dissipated in this resistance would necessitate a reduction in the rating of the motor if the resistance was mounted internally.

chain comprising a 2-inch transmitter and coincidence transmitter of the appropriate type. The phase-shift circuit is readily accessible to facilitate adjustments should the amplifier be required to work with alternative Magslips. The phase-shift is substantially unaffected by the level of the input signal.

A further function which is conveniently performed in the amplifier unit is the mixing of a stabilizing signal from an induction generator. A control is provided to vary the proportion of the feedback from this source, and phase-shift networks are incorporated to compensate for the phase difference between the induction generator output and the error signal from the Magslips.

The circuits of the two amplifiers are similar.

CHARACTERISTICS OF MUIRHEAD A.C. SERVOMOTORS

Motor Designation	1½-inch E-47-B/1	2-inch E-16-A	2-inch E-16-F	3-inch E-33-A
Overall length	4 in.	5 in.		6 in.
Diameter	1⅞ in.	2½ in.		3⅜ in.
Moment of inertia of rotor	0·2 oz. in.²	1 oz. in.²		4 oz. in.²
Supply frequency	50 c/s	50 c/s	400 c/s	50 c/s
Stalled torque	2 oz. in.	4 oz. in.	4·5 oz. in.	15 oz. in.
Power consumption (stalled)	14 W	30 W	60 W	60 W
No-load speed	2,200 r.p.m.	2,800 r.p.m.	7,000 r.p.m.	2,880 r.p.m.
Power consumption (no load)	10 W	15 W	17 W	20 W

SERVO AMPLIFIERS

Two servo amplifiers are available. Type D-614-D is suitable for use with the 50 c/s servomotor type E-16-A, whilst type D-614-E is suitable for use with the 400 c/s motor type E-16-F.

In a typical remote position control instrument servo, controlled by a Magslip transmitter and coincidence transmitter, the error signal from the latter is about 0·5 volt per degree of misalignment. In order to utilize the accuracy of the Magslips and to achieve a good response the servo amplifiers have been made capable of amplifying the signal resulting from a misalignment of the order of 0·25° (viz. 125 mV) to a level which will cause the servomotor to exert full torque. For smaller misalignments the amplifier response is linear, while for large misalignments, when the error signal may rise to about 30 volts, the amplifiers, although working under saturation conditions, present an output of reasonable waveform to the motor, with an amplitude sufficient to energize the motor fully, but not to overload it.

Since one phase of the servomotor is normally energized from the mains supply the servo amplifier is usually required to deliver a signal in phase quadrature with the mains. Part of the required phase-shift is introduced by the control Magslips and the remainder is introduced by the amplifier. The amplifier phase-shift is adjusted for use with a Magslip

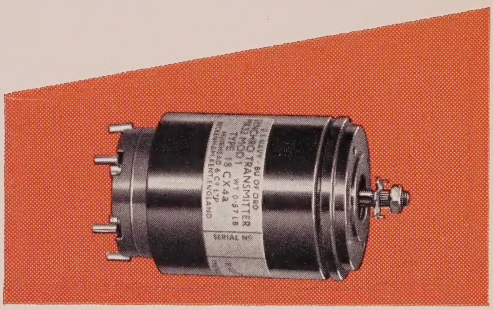
Phase-shifting networks are included in the initial stages to produce the required quadrature phase-change of the output. Associated with these are the induction generator phase-shift network and control potentiometer, and a gain control for the amplifier. Then follows a fairly conventional resistance capacitance-coupled amplifier, the latter stages of which are flatly tuned to the supply frequency to reduce the peakiness of the waveform under overload conditions. A push-pull output stage is provided which is capable of supplying sufficient power to enable the motor to exert full torque under stalled conditions. A small amount of H.T. and valve heater power is available for external use. This may be employed to supply associated circuits such as an error rate damping network or a D.C./A.C. inverter, and thus increase the range of application of the servo amplifier.

D-614-D SERVO AMPLIFIER

CHARACTERISTICS OF MUIRHEAD SERVO AMPLIFIERS

Type No.	D-614-D	D-614-E
Supply	110 and 200–250 V, 50 c/s	100–120 V, 400 c/s
Power consumption	80 watts	100 watts
Input signal for full output at maximum gain	20 mV	10 mV
Maximum output power	15 W	30 W
Maximum output voltage	50 volts	115 volts
Phase-shift (Including phase-shift in Magslip chain)	90° ± 10°	90° ± 10°
Residual output voltage	1 volt max.	2 volts max.

MUIRHEAD SYNCHROS



WE are now manufacturing a range of Size 18 synchros and servomotors for 115 V, 400 c/s operation, produced to American Bureau of Ordnance Specifications. The size number refers to the outside diameter of the synchro in tenths of an inch.

Three elements are available immediately; a control transmitter, a control transformer and a servomotor. With a suitable A.C. amplifier these elements can be used in a remote position control servo system. A mechanical input to the control transmitter results in an electrical error signal output from the control transformer. This is used to control the servomotor, which in turn drives the control transformer until its output is zero. At this point the system comes to rest in a new position corresponding to the position of the control transmitter.

18CX4a SIZE 18 CONTROL TRANSMITTER

This element employs a single-phase rotor mounted on single-row ball journal bearings, and a three-phase star-connected stator. The rotor is energized from the 115 V, 400 c/s supply through silver strip brushes and silver slip rings. The stator output voltage between terminals is 90 V, 400 c/s maximum.

18CT4a SIZE 18 CONTROL TRANSFORMER

This element employs a three-phase star-connected stator and a single-phase rotor. Bearings and rotor connexions are the same as for the 18CX4a element. The stator is energized from the control transmitter, and the stator voltage is therefore 90 V. The error voltage output from the rotor is 1 volt per degree of initial misalignment.

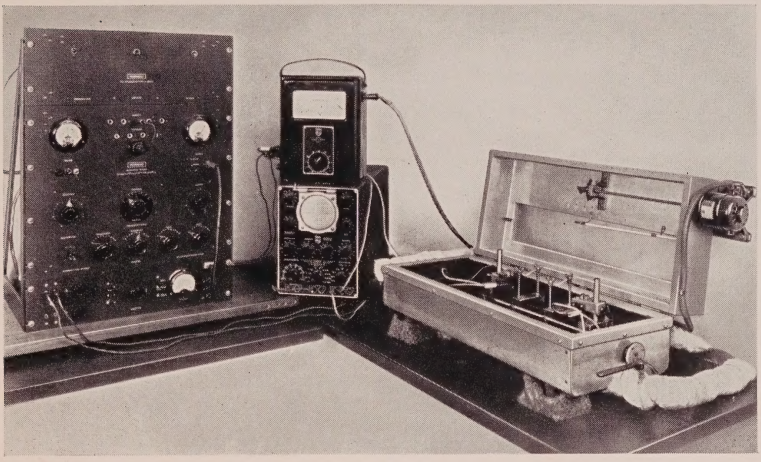
SIZE 18 SERVOMOTOR

This is an induction motor with a high-resistance squirrel-cage rotor and a 2-phase 8-pole stator. The maximum output power is about 2 watts. The reference phase is wound for 115 volts 400 c/s, but the control phase winding is in two parts which may be connected in series or parallel, and is thus suitable for either 115 volts or 57·5 volts.

Data sheets giving full technical details of these elements are available on request.

AN APPARATUS FOR THE MEASUREMENT OF DYNAMIC MECHANICAL PROPERTIES OF PLASTIC MATERIALS

By Dr W. P. van Oort*



Apparatus for vibration measurements on bars vibrating freely. The bar is normally supported on the two strings secured by wing nuts in the right-hand unit, but has been omitted from the photograph so that the electromagnets at either end can be seen more clearly. The driving power is derived from a D-105-A Muirhead-Wigan Decade Oscillator, which covers a frequency range of up to 111,100 c/s.

A BAR of rectangular cross-section is placed with the outer nodal points on two slack strings. The distance of these nodal points from the ends of the bar can be calculated from its dimensions, and from the total number of nodal points, which is dependent on the frequency at which the bar is vibrating.

The D-650-B Oscillator shown above has now superseded the D-105 Oscillator referred to on this page. As well as having a better performance it incorporates a continuously variable control which interpolates between the lowest decade steps up to 11,000 c/s, thus combining the accuracy and stability of a decade oscillator with the convenience of a continuously variable instrument.

A thin iron plate is attached to one end of the bar to enable it to be set into transverse vibration by means of a small electromagnet fed from an A.C. source of variable frequency. A second iron plate attached to the other end will now vibrate with the bar and a pick-up coil with a magnetic iron core placed opposite this plate will have induced in it an e.m.f. of the same frequency as that of the generator. After amplification this voltage can be measured with a valve voltmeter and, if desired, examined on a cathode ray oscilloscope.

The frequency of the generator is varied until the deflexion of the voltmeter reaches a maximum. At this point resonance has been reached and the dynamic modulus of elasticity of the bar can be calculated. The degree of damping can also be derived from the width of the resonance curve.

By varying the length and/or the thickness of the bar a fairly wide frequency range can be covered. By placing the assembly in an air thermostat, which can be either heated or cooled, measurements can take place at any desired temperature.

(Abstracted from an article originally published in *Transactions of Instruments and Measurements Conference*, Stockholm, 1952.)

*Royal Dutch Shell Laboratories, Amsterdam.

DEMONSTRATION AT DE BILT

At the Royal Netherlands Meteorological Office in de Bilt, Holland, we recently demonstrated our Mufax Weather Chart Transmitters and Recorders, which are now extensively used by meteorological organizations in many parts of the world for the rapid dissemination of weather information by wire or radio.

Our picture transmitters and receivers were also demonstrated, and representatives of the Dutch press and armed forces were thus able to examine a wide range of facsimile equipment under working conditions.

In the photograph our engineer is explaining the operation of a transmitter to Dr Warner, Director of the Meteorological Office.

NEW BOOK

Automatic Voltage Regulators and Stabilizers by G. N. Patchett Ph.D. B.Sc. A.M.I.E.E. M.I.R.E. 335 pages, 196 figures, 8¾-inch × 5¾-inch. 50/-. Published by Sir Isaac Pitman & Sons, London.

With the increase in accuracy of electrical measuring and calculating instruments the need for constant voltage supplies has become of primary importance. A book dealing exclusively with this subject is therefore assured of a welcome, since published material has so far been confined almost entirely to the technical journals.

The first impression gained on reading this textbook, which is written by an authority on the subject, is that it is really the author's notebook. Almost every type of apparatus is described, and although in the preface it is claimed that the descriptions, as far as possible, are of a general nature, a great many commercial circuits are discussed which are only variations of basic designs. The style of writing, too, is at times more in keeping with laboratory notes than a carefully edited book. The illustrations do not appear to have been selected with sufficient discrimination from an educational point of view, and far too many manufacturers' photographs have been included. For example, in Chapter 4, photographs of a small Variac and a motor-driven Variac add nothing to the information contained in the accompanying description and references.

At the start the author draws a distinction between voltage regulators and stabilizers by the explanation that the latter should more correctly be called *generator automatic voltage regulators*, and are restricted to maintaining a nearly constant output voltage notwithstanding variations of load and supply voltage, whilst the former, which should be known as *supply voltage regulators*, may regulate the actual supply voltage and even include the stabilizers.

After a short introductory chapter on types of regulators, the design specification and principle are set out. A brief description of the more common types of non-linear devices follows (in Chapter 6 this description is amplified) and the general part of the book is completed by a classification of regulators according to the position and type of the change-detection and regulating units. Chapter 4 deals with various regulators of the discontinuous-type, and Chapters 5 and 6, which together occupy 170 pages of the book, are devoted to continuous control regulators, electro-mechanical and electrical types each being given a separate chapter. Chapter 6 includes some 70 pages describing the various non-linear devices used for change (error) detection, and sets out clearly their practical limitations. This forms a unique addition to the book and by giving a figure of merit for each device provides a convenient means of comparing the performance of different types.

In the final chapter special voltage regulators such as those for three-phase generators are discussed and there is a brief account of 'hunting'. This phenomenon is regarded as too complex for this type of book, however, and the reader is given references to articles where detailed information can be found.

The subject is treated comprehensively throughout; in fact the main criticism is that insufficient pruning of descriptions has been made. Since the value of this book to students is specifically mentioned, and in view of its relatively high price, perhaps the inclusion of some problems for solution would also have been an advantage.

Nevertheless, in spite of these criticisms, the main purpose of the book is admirably fulfilled, and it can be recommended as a reference book of use to all who are interested in voltage regulators, of whatever size and type.

A. Cooper B.Sc.(Hons) A.M.I.E.E.

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